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ABSTRACT

In this paper a new conception of school science is set forth, based on the utilization of data collected in introductory college chemistry classrooms in a western university. Two sections of freshmen chemistry and several of the accompanying laboratory periods for the first weeks of the fall semester were observed. The methods of research were interpretive, requiring participant observation in science classrooms to see the moment-to-moment construction of school science by its participants. A sociocultural perspective was used to examine how teachers and students interact in the classroom and how these actions are constrained by the interpretations of larger social precepts. Sections include: (1) "Chemistry 100A: The First Lecture"; (2) "School Science--as a Rite of Passage; Separation; Transition; and Reincorporation" and (3) "Implications for Further Study." The bibliography contains 70 references. (KR)

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**SCHOOL SCIENCE
AS A RITE OF PASSAGE**

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SCHOOL SCIENCE AS A RITE OF PASSAGE

What goes on in science classrooms? Studies which focus on this question reveal that what goes on in science classrooms is teacher and student use of the textbook. Ninety percent of all science teachers use a textbook 95% of the time. Discourse analysis confirms that teacher talk primarily makes up what goes on in science classrooms, with the most likely format a variation of teacher question, student answer, teacher evaluation, teacher question (Lemke, 1989; Tobin and Gallagher, 1987). In spite of reform movements, students continue to spend much of their time in seatwork, completing worksheets, vocabulary definitions, and multiple-choice exams.

Although these conclusions tell us something about the science curriculum, we still don't know much about what goes on in science classrooms (Chubin, 1990; McDonnell, et al., 1990; Schwab, 1969; White and Tisher, 1986). Knowledge of what school science means to teachers and students and how that meaning is shaped by the contexts of schooling and society is important in understanding what goes on in science classrooms. However, most research on science classrooms has focused on observable features of the curriculum, such as activity structures and use of materials. Two notable exceptions are Stake and Easley's (1978) case studies of science education and Lemke's (1989) analysis of science classroom discourse. Stake and Easley focus on the institutional constraints on science education, and Lemke explores how science classroom discourse reflects societal values of

science. Neither of these studies, however, explore the meaning-perspectives of teacher and students. Both stop short of analyzing teacher and student perceptions and intentions behind their talk and actions.

This paper attempts to move beyond past science education research by providing a sociocultural examination of the curriculum-in-use in science classrooms to gain understanding of how face-to-face interactions between teachers and students in science classrooms shape and are shaped by notions about science, the scientific community, and American society in general. Ideas from the broader domains of schooling and society leak into the more specific local domain of the classroom, making curriculum not simply the result of individuals, whether they be teachers or students; nor only of a larger social order (Page, In Press). Instead, the science curriculum is both a social *and* cultural construction. This construction is ideosyncratic, i.e., particular to the teachers and students involved; as well as patterned, because classrooms are situated within schools as well as society. Important to this construction are the participants' meanings of schooling, society, science and the scientific community.

This alternative conception of curriculum defines school science as an ongoing negotiation of knowledge between students and teachers in particular institutional and social contexts (Page, In Press). As a sociocultural and political as well as scholastic process of meaning-making, school science can only be understood by examining everyday science lessons, or the curriculum-in-use. The phrase "curriculum-in-use" addresses the dynamic interaction between students, teachers, and subject matter.

Most studies in science education, for all their diversity, have a common problem: All analyze aspects of the science curriculum as static and

isolated. Much like the blind men and the elephant, these studies succeed in describing only part of the curriculum, resulting in misconceptions and partial understandings about the science curriculum as a whole. The science curriculum is more than the sum of its parts: the interrelationships between teacher, students, and subject matter must be examined as well.

Further problematic is that few studies situate these complex relationships within the larger contexts of school and society. Those which do examine contexts isolate certain facets of society (the school, the nature of science, gender, race), which results in an incomplete and deterministic representation of school science. Researchers, for example, focusing on the institutional constraints of schooling on the science curriculum, maintain that science is much like other subjects (Stake and Easley, 1978; Tobin and Gallagher, 1987; Weiss, 1987). The opportunity for learning is often sacrificed for control (Lemke, 1989; McNeil, 1988); teachers lower their cognitive demands so that students will engage (Tobin and Gallagher, 1987). Schools, because of their differing socioeconomic make-up, provide different access to materials, courses, quality teachers, and science experiences (Oakes, 1985, 1990).

Although these studies begin to identify the complexity of school science and the contexts which shape it, they present students and teachers as passive participants, and societal structures as totally determining features of the curriculum. The focus on the contexts of schooling leaves hidden the ways in which face-to-face interactions between teacher and student over subject matter limit the autonomy of larger social structures (Willis, 1977). However, students and teachers are active participants in the construction of school science. Even Lemke's analysis of classroom discourse, which focuses on both the contexts of schooling and the nature of

science, examines only how classroom talk legitimates the power of these structures instead of looking to see how classroom talk shapes schooling and science even as it is constrained by it. Failing to address how teachers and students shape science, Lemke sees student response to teacher talk as deterministic, understood only within the context of science or schooling. The cultural context--teacher and student feelings about and perceptions of science and schooling--is ignored. Little research has focused on what makes teacher and student actions over subject matter "sensible" to them (Spindler, 1982).

There are few studies which conceptualize school science as a sociocultural as well as scholastic process and which explore the relationship between the face-to-face interactions between teachers and students over subject matter and multiple social precepts as bidirectional. Research is needed that provides a dialectic between current theory and data and an extensive, thorough look into science classrooms, so as to shift our focus to the complexities of the practical school situation and to seek understanding as to the relationships between and within context, teacher, learner, and subject matter.

In this paper I set forth a new conception of school science, utilizing data collected in introductory college chemistry classrooms in a western university. Collecting data "by participating in the daily life of the group" to discover "their interpretations of the events" (Becker, 1958: 652), I observed two sections of freshmen chemistry and several of the accompanying laboratory periods for the first four weeks of the fall semester.

The methods of research are interpretive, requiring participant observation in science classrooms to see the moment-to-moment construction of school science by its participants. I utilize a sociocultural

perspective to examine both the "webs of significance" (Geertz, 1973: 5) teachers and students spin as they interact in science classrooms, and how these actions are constrained by their interpretations of larger social precepts. Although this study describes school science at the university level, it informs our understanding of science at all levels. Ambiguities and contradictions in the science curriculum constructed at the university level do not occur in a vacuum. Professor and student meaning-perspectives of schooling, science, and society have evolved over many years spent in classrooms. Teachers and students bring their ideas and understandings to the classroom and negotiate the curriculum, often with unintended results.

CHEMISTRY 100A: THE FIRST LECTURE

The first lecture in freshmen chemistry provides a good example of what goes on in science classrooms. The following narrative describes the first day of class for Chemistry 100A students:

The foyer of Science 2000 is a formidable one. Names of scientist after scientist are etched on metal plates, stretching the length of the foyer in an impressive representation of scientific history: Mendeleev, Bohr, Plank. . . . The lecture hall is huge and cavernous, sloping steeply down towards blackboards covered in chalked structures of complex organic compounds. In front of the lectern the organic professor explains a problem to two lingering students. As students make their seating choices, the entire lectern area begins to revolve and professor and students slowly disappear. A new professor comes into view as the other side of the revolving lectern settles into place. Two new blackboards are full of cryptic information about Chem 100A:

Assignment: Study Ch 1 in Chang. Read pages 3-19 in Student Handbook; Labs: Start this week. Prepare for expt #1 (except

you won't do unknown liquid in Part B); Problem Sets due:
Assign A (HBK p 25) due Friday (H8 choose best answer)

The professor begins his introductory notes--exam schedule, homework policy, laboratory arrangements). Some students are restless, tapping pencils, passing notes. Others slump on their stools, eyes toward the ceiling or wandering around the room, checking out classmates. Finally, introductions are over.

Now comes the sermon. Chemistry is a vertically structured course. The ideas and concepts you start with will get you through the course. The other important part about chemistry, and this holds true for other university courses, hopefully, concerns memorization. There are a bunch of things you need to memorize, you must be able to use them. However, as Einstein said, "Imagination is more important than knowledge". Okay, knowledge means memorization. What you are going to have to have is imagination. This will be the way this course will differ from high school courses.

At 1:48, with twelve minutes remaining, the professor turns to chapter one. "Okay, what is chemistry? Chemistry is the study of materials that make up matter." Students stir, sit up, and begin notetaking. With only minutes remaining in class, the professor introduces the topic of chemical change, illustrating the concept by using a hair dryer on a piece of paper previously taped to the blackboard. As the paper heats up, a change occurs in the chemical which had been painted on the paper, revealing the blue outline of a happy face.

This is a happy face. (pause, students laugh). And ah, when you ah, apply heat to this, chemical change occurs, and pink becomes blue. . . a simple thing that takes place. However, we know its a chemical change because by reversing the conditions, say, by cooling it off, the blue doesn't go back to pink.

After this demonstration, the professor turns to the two happy face balloons attached to the laboratory bench. One is filled with hydrogen and

the other with helium. Students seem to know that what is coming; they lean forward in their seats and grin. The professor first holds up a match, then dissolves the class into laughter as he attaches it to a six-foot pole. He pops the first balloon, a happy face filled with helium, commenting, "There is no chemical change associated with this reaction". As he touches a match to the second balloon, students grimace in anticipation. BOOM! WOOSH! The room vibrates with the explosion. Instant chatter and shaky laughter occur as students reassure each other. Somehow united through this reaction, students have witnessed one of the most exciting demonstrations chemistry professors offer first year students, and are joined together through chemical change. The professor lets the chatter die down, and closes the class with a final remark, "We could spend a lifetime examining the chemical change in that reaction".

SCHOOL SCIENCE

What meanings did students and teacher make of this first (and subsequent) lectures in chemistry? What did students think when the professor suggested that their high school courses lacked imagination. How do they understand science? Do they really believe that they could spend a lifetime examining the hydrogen reaction? Do they understand the concept of an "unknown liquid"? Lemke maintains that science as practiced and science as taught are very different. What differences do students see?

Science educators currently conceptualize school science as a pipeline which converts "crude" talent into a "refined", finished product (Chubin, 1990; Krieger, 1990; Office of Technology Assessment (OTA), 1988). This metaphor makes teachers' and students' experiences in and perceptions of school science unimportant. The curriculum is merely a technical conduit; students "flow" through the curriculum with varying degrees of viscosity.

Linking school science to a pipeline calls attention to the school's more general function of sorting and selecting students: Science courses pump some students through the pipeline and filter others out. The pipeline is recognized as semipermeable, with many points of entry and exit through which different students pass with different degrees of ease (Aldridge, 1988, 1989; Chubin, 1990). However, the school-science-as-a-pipeline metaphor highlights as well as hides features of the curriculum, bringing with it social and cultural implications (Bono, 1990; Black, 1962; Kliebard, 1982). It suggests that science works to differentially pump through or filter out students, but ignores how the pumping and filtering occur, as well as teachers' and students' response to and interpretation of these processes.

In contrast to this functionalist perspective on curriculum, other theorists maintain that school science is an ongoing negotiation of knowledge between students and teachers in particular institutional and social contexts. As an alternative to the pipeline metaphor, school science can also be conceptualized as a rite of passage. Like the pipeline metaphor, school science as a rite of passage reflects the lengthy process from "grade school to grad school", the subtitle of a recent Office of Technology Assessment report on educating scientists. However, within the framework of ritual theory, teachers and students are recognized as active participants in the construction of school science as opposed to barrels of crude oil.

School Science as a Rite of Passage

Rites of passage are the means by which individuals are eased through the difficulties of transition from one social role to another, such as from school student to scientist or member of the scientific community. As Van Gennep (1960: 3) notes:

The life of an individual in any society is a series of passages from one age to another and from one occupation to another. Wherever there are fine distinctions among age or occupational groups progression from one group to the next is accompanied by special acts, like those which make up apprenticeship in our trades. Transitions from group to group and from one social situation to the next are looked on as implicit in the very fact of existence, so that a man's life comes to be made up of a succession of stages with similar ends and beginnings: birth, social puberty, marriage, fatherhood, advancement to a higher class, occupational specialization, and death. For every one of these events there are ceremonies whose essential purpose it to enable the individual to pass from one defined position to another which is equally well defined.

Rites of passage contain ritual elements that prepare the individual for learning, reinforce particular ideology, and perpetuate traditions (Turner, 1987; Van Gennep, 1960). These ritual elements may contain repetition, dramatic and evocative presentational style, ordeals, and symbolic inversion (Turner, 1987). School science contains components that mirror each of these elements. Homework problems and laboratory activities often require the same mental and physical skills over and over again. The hydrogen demonstration is dramatic and evocative. Students endure mental ordeal through extensive memorization and stressful testing situations. The laboratory setting is only one of the symbolic opposites to students' everyday world.

Education is impossible without ritual (Varenne, 1981). Appropriating John Dewey's insistence that education is most successful when students are constantly involved in doing -- acting out what they are learning, Varenne argues that this is equally true of cultural knowledge. Thus, when chemistry students are involved in ritualistic activities such as homework, laboratory activities, and observing demonstrations, they develop an understanding of the values and actions appropriate for members of the scientific community.

Rites of passage have meanings both in their functional implications for the community the individual is entering, as well as for the individual. The ceremonies make them the kind of persons they must become if the community is to function effectively, and also expose the individual to the privileges and responsibilities of group membership. One major characteristic of scientists is that they have power, identified by chemistry professors even on the first day of the course. In the following overhead transparency, the professor's use of the word "control" is not incidental.

Chemistry - study of materials and changes in materials.

Control of chemicals. Control of chemical change.

Chemists use various means to find out what chemical changes are possible; they then try to make these chemical changes happen as quickly as possible and at or near ambient temperature.

"possible": domain of thermodynamics

"quickly": domain of kinetics

Chemists control chemical changes; chemical changes are powerful. A later discussion of physical properties, illustrated with samples of copper and zinc metal, further elaborated the power chemists have. As one professor noted:

(The periodic table is) mind boggling to me. We have 2% of all the elements right here. Everything that exists in our world is made out of 90 building blocks. I want you to think about that. Where do they come from? Why are they here? What is their purpose? It gives you an idea of the power a trained chemist has in his or her hands.

Demonstrations also invoke power. In spite of the scientific explanation offered, demonstrations retain a magical, almost supernatural element. This seems to be one of the purposes of demonstrations. Although the hydrogen demonstration was used by both professors on the first day of the course, it was utilized in different contexts and neither professor provided much explanation of the chemistry involved in the reaction. One

professor simply suggested that "(we) take a little break here and do a demo". Through demonstrations, students are seduced by the power of chemistry. Distinctions between those who know how to control the world through chemical (and especially nuclear) change and those who don't begin to blur as students realize that they could be part of that empowered community. Chemistry is represented as magical; chemists are magicians with special powers.

Separation, Transition, and Reincorporation

The school-science-as-a-rite-of-passage metaphor exposes certain problems within the science curriculum that are not seen in the pipeline metaphor. The rite of passage into science and the scientific community is ambiguous and extended. The goals and means to those goals are not clearly established, resulting in uncertain student and teacher understandings of science and society, of roles and what counts as knowledge. The ambiguity and contradictory character of school science can be understood through examination of the three stages of rites of passage.

Passage rites consist of three consecutive elements: separation, transition, and reincorporation (Turner, 1987; Van Gennep, 1960; Vizedom, 1976). The rite of passage into membership in the scientific community is actually a "series of rites signifying separation from, transition through, and incorporation into culturally recognized status and roles. Within the larger rite there are also numerous other rites and ceremonials indicating partial transitions and new role relationships" (Fisher, 1969: 291). Science students are separated literally as well as symbolically. Even as they enter the lecture hall, freshmen chemistry students cross a symbolic threshold named to invoke power: "Science 2000" couples the ability of science to solve our problems with the 21st century.

Separation

The first phase in a rite of passage, separation, signifies the detachment of the individual from a fixed point in the social structure (Turner, 1987). Detachment in the school science rite of passage is problematic. The American education system seeks not only to identify and prepare a select group for future careers in science and engineering, but also wants to teach all students to be scientifically literate so that they can make intelligent decisions if a society ever increasingly dependent on technology and science. This makes confusing, for both teachers and students, the point of separation as well as who is being separated and from what. Research documents that some students decide to become scientists as early as third grade; others decide just as early that science is not for them (Berryman, 1983; Chambers, 1982; OTA, 1988). As well, students have been known to change their minds at every level of education (OTA, 1988). Because of increased university requirements, most college-bound students take two years of academic science. Only a small percentage of these students plan to pursue a career in the sciences (Brunkhorst and Yager suggest that 98% of precollege students will not work in fields of science or engineering). Thus, high school chemistry and biology do not separate future members of the scientific community from those who do not plan a career in the sciences. Unfortunately, many high school teachers and college professors continue to perceive the major goal of high school science courses as preparation for college. The chemistry curriculum is developed and implemented on that presumption (Blasko, 1987), confusing potential scientists as well as future "scientifically literate" citizens as to the purposes of the course and overall value of science (Young, 1986). Chemistry teachers express frustration in deciding which students to base their

curriculum on; the resulting curriculum is a confusing amalgamation of these two goals. By the end of high school, a dichotomy between the "technology adept and the technophobic" (Shipman, 186: 4) is firmly established in our culture. Separation has occurred, even if this particular separation was not intended. Science educators have not determined how to be effective in the achievement of the two goals of school science.

By the time students enter Science 2000 for their first lecture in chemistry, however, their separation is more defined. Students in Chemistry 100A have undergone a partial transition and are already incorporated into the scientific community at a low level. Most plan a career in science, engineering, or a related field. When they cross the threshold of Science 2000 and later the threshold of their chemistry laboratory, they already identify themselves as future members of the scientific community. They are moving into a more definite phase of liminality, or transition.

Transition

College freshman chemistry most appropriately represents the liminal stage in a rite of passage. During this period, the state of the ritual subject is ambiguous; few of the attributes of the past or coming state are present in this period. Instead, both states may be grossly distorted through exaggerated representations and symbolism (Turner, 1987). Turner maintains that the purpose of these exaggerations is not irrational but instead thought-provoking, designed to "startle neophytes into thinking about objects, persons, relationships, and features of their environment they have hitherto taken for granted" (Turner, 1987: 14). The liminal period is designed to both induce and allay personal and social stress. This dualistic nature is evidenced even on the first day of Chemistry 100A, as student anxiety, heightened by the portentous lecture hall and cryptic messages on

the blackboard, is eased by the sight of happy face balloons reassuring them of friends within. Deliberate attempts to heighten anxiety produces mixed results: an adrenaline rush in the student, an undefined feeling that she will be able to rise to the occasion; and a sinking feeling in the stomach that he doesn't have what it takes. Even as happy faces are smiling down upon them, students are warned of potentially dangerous laboratory experiments, difficult subject matter, extensive homework problems, and strenuous and difficult examinations.

The emphasis on the manipulation of numbers and problem-solving also serves to heighten anxiety. On the first day of class one professor noted, "We mostly go for numbers on the exam because, well, I don't know . . . I'm not going to ask you what chemistry is on an exam". In the week following, he cautioned his students that, "What's coming up is critically important (preliminary to providing examples of mole-gram calculations). You can sit around and wonder, 'What is this mole thing?', but that's a philosophical question. Just accept that a mole has 6.02×10^{23} things in it". The importance of manipulating numbers through calculations is over exaggerated to the point that it is emphasized as more important than understanding principles and concepts.

Most students respond to this emphasis by focusing in on references to numbers in class. During a brief mention of conversion factors, one of the professors noted that "1 inch is equal to exactly 2.5400 centimeters," suggesting to students that they "memorize that one. It will help you this quarter but also your entire life". Students dutifully wrote the conversion factor down. The other professor remarked that two mathematicians in Chicago had recently set a new record for the value of pi, replacing the previous Japanese record by determining the value to 408,000,000 figures.

When he added that the end of this number would be 9000 miles away from the beginning, students got very animated, some chattering to each other, others whispering "Sh-h-h-h!" so that the professor could continue.

Conversion factors and constants have a utilitarian as well as a symbolic nature, spoken of in hallowed tones. Dr. Holmes even mentioned that there is a platinum iridium bar in France at controlled temperature, pressure, and environmental conditions, so that we can always be assured that one meter (of length) is indeed one meter. Precision and accuracy were also discussed in terms of numbers; the concept of significant digits is very important. The method of scientific notation is covered in lecture because chemists (and scientists in general) often work with very large or very small numbers, but the emphasis serves to intensify student anxiety.

The act of problem solving becomes a sacred ritual, performed again and again at increasing levels of sophistication. One of the professors suggested that to students that they should be so intimate with numbers that they "feel comfortable about (their calculations)". Solving problems based on the use of canceling units is so important the inability to do so was related to death. An overhead transparency reiterated that "mole-to-gram and gram-to-mole conversions are very important" and that students would be "dead if (they) can't do these!".

The liminal period of a rite of passage is marked by such exaggerations (Turner, 1987). Unfortunately, this particular exaggeration has negative consequences. Problem-solving is reduced to an exercise in which the correct algorithm simply needs to be plugged in, and the answer calculated to the correct number of significant figures. The creative and hermeneutical aspects of problem-solving are lost. This simplistic approach to doing science is reinforced by the lack of discussion of past discoveries in

science. Kuhn (1962) argues that one of the major differences between science and other disciplines lies precisely in the attitude that the practicing scientist takes toward the history of his discipline. In comparing art and science, Kuhn tells us:

In no area is the contrast between art and science clearer. Science textbooks are studded with the names and sometimes with portraits of old heroes, but only historians read old scientific works. In science new breakthrough(s) do initiate the removal of suddenly outdated books and journals from their active position in a science library to the destitute of a general depository. Unlike art, science destroys its past. (Bernstein, 1983: 246)

Bernstein suggests that knowledge of science's past and study of its history are essential for philosophers and historians who want to understand the nature or image of science. The lack of introduction to the history and philosophy of science and the richness of discovery produces a void in student perceptions and beliefs about science. In an introduction of atomic theory, Dalton's theory was presented without much preliminary information and nothing was said about the revolutionary aspects of the ideas involved:

We really didn't have a good idea of modern atomic theory up until the beginning of the 1800s. John Dalton is usually given most of the credit for the first reasonable atomic theory. His work of course was built upon (as science is) the work of many other people. In just a few words, Dalton proposed that the elements are composed of atoms, individual atoms, all of which are the same, like the atoms of lithium. A piece of lithium, and all of atoms of lithium are the same . . . a piece of lithium from somewhere else, all those atoms are the same: certain mass, certain composition, certain size. He did not know about that, he just proposed that they were atoms.

There is no suggestion of the complexity of arriving at the notion of atoms; no hint that this was once an arguable point. Although the professor

later remarked that Dalton was a meteorologist and that his scientific interest was the chemistry of the atmosphere in an attempt to illustrate how Dalton became interested in the notions of atoms, no students noted that point. A student I later borrowed a lecture recording from had actually turned the tape recorder off during these remarks.

Within the liminal period of transition to membership in the scientific community, students are provided an environment in which to practice their new social identity. Rituals which occur here are often elaborate and exotic: the meaning of many of these activities appears obscure to students. One student remarked to another student the day after the first laboratory, "... she didn't explain it at all. All I know is that I have to find the density of the metal." Performance of certain rites is required for ultimate membership in the group, but the purposes of these rites are muddy for students as well as professors. On the first day of lecture, the laboratory was described as "not count(ing) all that much of the grade," but students were told that they "must pass the lab" because "we have to verify this particular set of experiences. You must attend and pass lab to pass this course". Students were also informed that

almost all possible questions that will come to your mind are included in the handbook, including what you have to do to pass the lab; which I can't remember. (Students laugh at this remark). You have to pass five or six of the eight labs to pass the lab. But if you fail the lab, you fail the course. You got to go to the lab, you got to do the three experiments.

Here again distortion occurs. The focus on "passing the lab" and "failing the course" is what is emphasized, not the enterprise of science. A two-faced nature of science has dominated science education practice during the twentieth century: science as content and product versus science as

inquiry and process. School science, which focuses almost exclusively on the content of science, presents an incomplete representation of science (Duschl, 1990). Science has been conceptualized as a fantastic game of puzzle-solving (Driver, 1975; McCain and Segal, 1983; Mitroff, 1979; Yager, 1988). Accordingly, the transition period should include preparation for playing and practice of this game. This emphasis on "passing the lab" results in a representation of science which focuses less on the game of science and more on the "game of making the grade." School science, already an incomplete representation, is now distorted through misrepresentation. Although one professor remarked that "chemistry is an experimental science" and that the laboratory would provide students with "opportunities to engage in real science", he then provided a more powerful motivation for attending laboratory by asking: "Are we serious about this course? Yes, so come to lab, do the labwork, and pile up those points". The game of science is secondary to the game of "making the grade."

The purpose of laboratory activities becomes clearer when seen as part of the transition period of a rite of passage. Rather than merely a means of "piling up points", the laboratory experience provides students with the opportunity to act out their future roles. Students not only experience how to titrate an unknown concentration of acid, use an electronic balance, or calculate the density of a solid based on laboratory observations. Through 'lab' they also involve themselves in activities that initiate them into the scientific community. The unfamiliar and cold nature of the laboratory room slowly becomes a welcoming place. What were alien objects become more casually used than the toaster in a dormitory kitchen. Lab equipment becomes familiar; they feel at home amid the sterile and bleak assortment of institutionalized sinks, beakers, ring stands, and ugly

black lab tables. Odors, once met with wrinkled noses and obvious grimaces, now produce mental pictures of particularly memorable laboratory experiences; a date made between titration trials or the moment when the experiment finally "worked" results matched the mathematical calculations with a good yield percentage.

The laboratory is also a scarring experience, in a physical sense as well as a mental one. It is a rare first year student who does not burn a finger, even though they know that "hot glass looks the same as cold glass". Breakage is lorded over; the lab floors amplify the sound of breaking glass, signaling an opportunity to see who broke what. The threat of chemical exposure also hangs over the heads of most students, so much so that one professor felt compelled to remark:

I want to mention, 'cause I know from experience, that there are some students, some Chem 1 students, are chemophobic (long pause, some students laugh) meaning . . . afraid of chemicals . . . ah, because . . . they will do bad things to your body. (Laughter) Be assured that . . . the people in charge of the course, the teaching assistants, . . . ah, are not going to put you in a situation where you're going to get a dangerous chemical exposure. We already know about this. We don't want ourselves exposed to, to, ah, a dangerous chemical. You will always be advised in a lab what the safety precautions are, if there are anything, anything is dangerous, when to work in a hood, when not to work in a hood. So, ah, be confident that we have your best interests in mind.

Students are confused and unsure; there's always the possibility of doing something wrong and injuring yourself in the process. The language is obscure and often laced with double meanings. One teaching assistant remarked that she would "take roll, and then we'll dissect the lab". She meant that students would split into groups. A brief safety lecture included multiple negatives: No shorts! No open-toes shoes! No nylons! The teaching

assistant warned of chemicals dissolving nylons, eating holes through nice clothes (so wear old jeans or sweats), and pointed out the location of the fire extinguisher, fire alarm, chemical shower, and eyewash, although, as she pointed out, her students would not need to use the latter because "the minute I find you with your goggles off, you're going home."

The laboratory room is sacred -- not just anyone is allowed admittance. The process of writing a laboratory report is outlined, and although it seems difficult, students begin to feel superior; after all, they are doing scientific experimentation, working with "unknowns", mixing dangerous chemicals and using very expensive equipment. Code words which had little meaning in lecture slowly begin to take on character. A capillary tube is utilized in a melting point experiment; "100 mls" becomes an estimable quantity; rubber tubing is used to connect the Bunsen Burner to the gas jet. Through the laboratory experience, students are initiated into their new world, tough but prestigious, exciting and sometimes right out of science fiction. The dualistic nature of the experience is effective: Students recognize the further separation from their nonscience-oriented peers as then hone their laboratory skills and gain confidence in their new status.

Reincorporation

The reincorporation stage comes much later in the life of a student, and like the process of separation, is lengthy and consists of more than one transition. It is made more problematic because the scientific community is a hierarchy of authority and prestige:

The small group at the center of communication and influence . . . enjoy full knowledge of the mystery and control over the discipline. Around this central group, usually based in the universities, are larger groups concerned with more than the use than with the advancement of scientific knowledge. They

are outside the informal network of communication that links those at the center and have a restricted view of the way new evidence is produced. Finally, around the frontiers of each scientific community are the public, including students qualifying for entry. Here the communal private language, the conventions governing and reporting of research, are not fully understood (Shipman, 1972: 2).

Because of the hierarchial arrangement of the scientific community, the reincorporation period requires continuous adjustment to new roles. These partial transitions make this stage difficult. The transition period is itself a partial reincorporation. Students are reincorporated into the scientific community at various levels; some are excluded altogether. Exclusion can occur at all three stages--separation, transition, or reincorporation.

The sorting and selecting of students is natural; introductory science courses purposefully "weed out" poorer students, selecting those who are academically able to handle the rigor of further study. However, the excluding of certain are not always based on academic ability (Kelly, 1987). Social constraints have prevented certain groups, such as females and minorities, from gaining entrance and persisting in science (Orr, 1987; LaFollette, 1990; Kahle and Matyas, 1987). Independent of academic ability, many students resist school science and avoid further study. Data for college-bound seniors show that although the same fraction of females, Blacks, Hispanics, and white males take introductory level science courses, wide disparities begin to emerge at more advance levels (Fordham, 1988; Lee, 1987; Linn, et al., 1987; Oakes, 1985, 1990; Orr, 1987; Weiss, 1987).

The Contradictory Nature of Science

Reincorporation is also problematic because the enterprise of science is contradictory. Price (1986), using a thermodynamics metaphor to analyze

science and the scientific community, compares four general characteristics of gas behavior to characteristics of the scientific community: volume, velocity distribution of molecules, interactions between molecules, and properties of the gas as a whole. Within each of these categories are major contradictions, resulting from disagreement over what scientists do, how they interact with each other, how they are organized within the community, what their responsibility is to society, and the political, social, and cultural implications of science. The scientific community presents logical, ordered and progressive representations of acts of discovery, while historiography reveals that theories were often serendipitously discovered by scientists while "messing about in science," or resulting in a revolution of ideas (Kuhn, 1962; Wolpert and Richards, 1988); it pictures friendly, collaborative colleagues sharing a Nobel Prize instead of colleagues in intense competition with each other, often ostracized for their research and even willing to filch another's discovery or at least the credit for it (Bourdieu, 1981; Cole, 1979; Collins and Restivo, 1983; Gornick, 1990; Sayer, 1975); and it outlines a logical and simplistic pathway to knowledge as opposed to a complex, creative and hermeneutical process of knowing (Bernstein, 1983; Kuhn, 1962). Feminist scholars argue that science is laden with the values of an elite, Western and masculine society (Harding, 1986; Harding and O'Barr, 1987; Keller, 1985; Reed, 1978).

Students enter science classrooms with notions about the nature of science and the scientific community (Lemke, 1989; Mead and Metraux, 1957; Reif, 1961; Solomon, 1983). Embedded within a complex of multiple contexts, including the school, scientific community, public, and democratic society, school science is an ambiguous amalgamation of conflicting

propositions. What is the use of science? Who should science be for? Who does science serve? Is science good or evil?

American society, in general, approves of science, respects scientific genius, and expects great benefits from research. However, society also questions the uses of science and the risks of technology (LaFollette, 1990). Science has become thoroughly incorporated into American culture -- scientists routinely appear on the news, in commercial endorsements, and conclusions reached in laboratories help justify legislation, policies, and personal decisions -- but the public is also skeptical of science. Political movements such as Greenpeace derive part of their energy from a denial of science's authority (LaFollette, 1990). Science is not assessed in terms of benefits and risks; it has lost its moral authority and value (Calvora, 1988).

The ambiguity of current public attitudes did not result from any one event or use of science. The prominence of science as a cultural symbol arose gradually through the 1900s, and skepticism grew alongside of it. Some skepticism resulted from concerns about our nation's economic future and strong beliefs that personal well-being may not be automatic (LaFollette, 1990). Other skepticism may be the result of continued tension between science and religious philosophy. Adults not only remain ambivalent about the value of science and technology in society, but also remain hazy about what a scientist even does (Chubin, 1990; Ryan, 1987; Schibeci, 1987; Smith and Erb, 1986).

These ambivalent and ambiguous notions leak into science classrooms, held not only by students and their parents, but by administrators and even science teachers themselves. Research on student perceptions of scientists reveal that elementary, secondary, and university students have ambivalent images of scientists (Gardner, 1987; Mead and Metraux, 1957). Beardslee

and O'Dowd (1961) surveyed 1200 college undergraduates and formed a composite picture of the scientist as a highly intelligent, individualistic, radical, socially withdrawn and depressed individual who had an ugly wife and an unhappy home life. Chambers (1982), after administering the "Draw-a-Scientist Test" to kindergarten through fifth grade children across the United States and Canada, concluded that these stereotypes become embedded in student thinking at the elementary level. With occasional exceptions, kindergarten and first grade children draw almost none of the seven indicators chosen by Chambers as indicators of the standard image of the scientist (lab coat, eyeglasses, facial hair, symbols of research, symbols of knowledge, technology, and relevant captions). By fifth grade, however, the majority of students draw three or four indicators; a few pictures exhibit six or seven. The stereotype of the scientist increases as students advance through school.

Science and school science are both ambiguous and contradictory. The relationship between them is complex because they are both shaped by human meaning, constructed independently as well as in relation to each other. One way to understand their relationship is to conceptualize school science as a rite of passage into science. The contradictory and ambiguous character of school science is made explicit when examined in the stages of separation, transition, and reincorporation of the passage rite.

IMPLICATIONS FOR FURTHER STUDY

Representing school science as a rite of passage allows us to see numerous problems: the extensive and ambiguous period of separation, the distortion of science due to exaggerations within the transition period, the hierarchial arrangement of the scientific community and exclusionary characteristics of the transition stage of the rite of passage, the

contradictions within science as an enterprise, and the ambivalent attitudes of society towards science. Because of the confusion students encounter as they struggle with school science, it is not surprising that they avoid careers in science and engineering. Conceptualizing school science as a rite of passage provides a lens through which to look at what goes on in science classrooms, but further research is needed to understand the complex relationship between science and school science, particularly at the secondary and elementary levels of education. Use of the rite of passage metaphor allows us to examine the meanings teachers and students make of science and school science as they negotiate the curriculum.

This metaphor also provides us with the means of exploring the exclusionary nature of science. Individuals in classrooms contribute unique meanings of science, schooling, and society as they negotiate knowledge and roles within these same contexts. As students experience and understand school science in multiple ways, they are differentially incorporated into science and the scientific community. Not simply a matter of tracking or access to materials as Oakes (1985, 1990) would suggest, students actively participate in their own exclusion from science, acting in ways that are sensible to them. Research is needed to explicate the processes through which resistance to as well as engagement in school science occurs so that effective policy decisions can be made which will facilitate the recruitment and retention of students in science.

And finally, this metaphor holds promise because it relates the transition from student to scientist (or scientifically literate citizen) to the wider transition from child to adult. As adolescent initiations mediate the discontinuity in American society between childhood and adult roles

(Benedict, 1938), so school science mediates between school student and member of the scientific community. As Lemke notes:

Science does not stand outside the system of social values . . . it depends on socially shared habits, practices, and resources that each individual (has) because she is a member of a community with a history and a system of basic values.

As adolescents become adults, they begin to participate in the "American cultural dialogue" (Spindler, 1990: 1). Science is very much a part of that dialogue. What goes on in science classrooms must be placed within this wider context.

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